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# A case-matched validation study of anatomic severity grade score in predicting reinterventions after endovascular aortic aneurysm repair

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***Background:*** **In 2002, the Society for Vascular Surgery created the anatomic severity grading (ASG) score to classify abdominal aortic aneurysms (AAAs). Our objective was to identify the predictive capability and cutoff value of preoperative ASG score for reintervention after endovascular aneurysm repair (EVAR).**

***Methods:*** **We completed a retrospective review of AAA patients treated with elective EVAR from 2007 through 2011. Patients who had reinterventions as well as preoperative M2S (M2S Inc, West Lebanon, NH) three-dimensional reconstructions were identified and compared with a case-matched control group of patients without reintervention. ASG component scores (neck, aortic, and iliac) and total ASG scores were calculated using M2S software.**

***Results:*** **Of the 623 patients treated with EVAR, 79 (13%) had reinterventions of which 45 had preoperative M2S three-dimensional reconstructions available for ASG score calculation. The reintervention group (mean age, 74 ± 8; 80% male) had a mean ASG score of 18 ± 5 (range, 8-30) compared with a cohort of 45 EVAR patients (mean age, 74 ± 7; 80% male) who had a mean ASG score of 13 ± 4 (range, 6-21; *P* < .0001). The mean AAA diameter for all patients was 52 mm ± 14 and was not significantly different between the groups.**

**After area under the receiver-operating curve analysis, an ASG score of 17 was highly predictive for reintervention (area = 0.8; sensitivity = 60%; specificity = 78%; positive predictive value = 73%; negative predictive value = 66%). An ASG score of 13 was highly predictive for freedom from reintervention (sensitivity = 93%; specificity = 47%; positive predictive value = 64%; negative predictive value = 88%). The lowest ASG score that yielded a 100% reintervention rate was 22. The majority of reinterventions fell into three categories: proximal extension cuff (n = 18; 40%), distal extension limb (n = 7; 16%), and type II endoleak embolization (n = 13; 29%). Those that received proximal extensions had significantly higher mean total ASG score (19 vs 15; *P* = .0005), mean neck score (3.28 vs 2.36; *P* = .047), and mean aorta score (7.39 vs 2.36; *P* = .004). Those that received distal extensions had a significantly higher mean iliac score (9.00 vs 6.86; *P* = .013), and those that required an embolization had a significantly higher mean aorta branch score (1.92 vs 1.19; *P* = .017).**

***Conclusions:*** **Preoperative total ASG score strongly predicts reintervention after EVAR. Use of a cutoff ASG value predictive of prohibitive reintervention rates could help guide the decision between endovascular vs open AAA repair. (J Vasc Surg 2013;58:582-8.)**

Several large, randomized trials have suggested that endovascular aneurysm repair (EVAR) can offer patients with abdominal aortic aneurysms (AAAs) greater than 5-5.5 cm in diameter a surgical option that is both less invasive and less morbid compared with open repair (OR).[1-3] Long-term follow-up on these patients has shown that this early advantage is lost by around 2 years postprocedure. This is likely attributed to the increased rate of graft-related complications and reinterventions in the EVAR groups compared with the OR groups.[4,5] When comparing two groups of EVAR patients (a group deemed physically fit for either EVAR or OR and a group that underwent EVAR after being deemed unfit for OR), the rate of graft-related complications and reintervention rates were remarkably similar, suggesting factors other than fitness contribute to these outcomes.[6]

Despite this, advancements in surgical techniques, newer grafts designed to overcome unfavorable anatomy, and imaging advances that have allowed for more precise preoperative planning, have led to the use of EVAR in patients previously deemed unsuitable because of unfavorable aortoiliac anatomy. These technological advances are expected to lead to a continuous increase in reintervention rates from the use of EVAR on patients previously considered anatomically marginal candidates.[7]

This calls into question the existence of threshold to answer who is suitable for EVAR and how is suitability best determined. Rutherford states that despite the worrisome drawbacks (questionable long-term durability, similar overall mortality as OR, higher costs, higher reintervention rates, and the need for an indefinite continuation of surveillance), EVAR is an appropriate treatment in patients with "suitable anatomy." Its use works well in conjunction

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**Table I.** ASG score calculation parameters[10]

| *Attribute* | *Absent = 0* | *Mild = 1* | *Moderate = 2* | *Severe = 3* |
|---|---|---|---|---|
| Aortic neck | | | | |
| Length ($L$) | $L > 25$ mm | $15 < L < 25$ mm | $10 < L < 15$ mm | $L < 10$ mm |
| Diameter (d) | d < 24 mm | 24 < d < 26 mm | 26 < d < 28 mm | d > 28 mm |
| Angle | >150° | 150° < angle < 135° | 135° < angle < 120° | Angle < 120° |
| Calcification/thrombus | <25% | 25%-50% | >50% | — |
| Aortic aneurysm | | | | |
| Angulation and tortuosity | | | | |
| Aortic tortuosity index (T) | T < 1.05 | 1.05 < T < 1.15 | 1.15 < T < 1.2 | T > 1.2 |
| Aortic angle ($\Phi$) | 160°-180° | 140°-159° | 120°-139° | <120° |
| Thrombus | 0 | <25% | 25%-50% | >50% |
| Aortic branch vessels | No vessels | One lumbar/IMA | Two vessels d < 4 mm | Two vessels IMA d > 4 mm |
| Pelvic perfusion | Patent bilateral IIA | Single IIA occlusion | Single IIA occlusion Contralateral IIA >50% stenosis | Bilateral IIA occlusion |
| Iliac artery | | | | |
| Calcification | None | <25% vessel length | 25%-50% vessel length | >50% vessel length |
| Diameter/occlusive disease | d > 10 mm<br>No occlusive disease | 8 < d < 10 mm<br>No stenosis <7 mm diameter or >3 cm long | 7 < d < 8 mm<br>Focal stenosis <7 mm diameter and <3 cm in length | d < 7 mm<br>Stenosis <7-mm diameter and >3 cm in length<br>More than one focal stenosis <7-mm diameter |
| Angulation and tortuosity | | | | |
| Iliac tortuosity index ($\tau$) | $\tau < 1.25$ | $1.25 < \tau < 1.5$ | $1.5 < \tau < 1.6$ | $\tau > 1.6$ |
| Iliac angle ($\phi$) | 160°-180° | 121°-159° | 90°-120° | <90° |
| Iliac artery sealing zone | | | | |
| Length ($L$) | $L > 30$ mm | $20 < L < 30$ mm | $10 < L < 20$ mm | $L < 10$ mm |
| Diameter (d) | d < 12.5 mm | 12.5 < d < 14.5 mm | 14.5 < d < 17 mm | d > 17 mm |

*ASG,* Anatomic severity grading; *IIA,* internal iliac artery; *IMA,* inferior mesenteric artery.

with recent individualized guidelines for the treatment of AAAs as discussed by the American Association for Vascular Surgery and the Society for Vascular Surgery (AAVS/SVS).[8,9]

Based on these observations, the need has arisen for a way to stratify candidates for EVAR based on the anatomy of their aneurysm. In 2002, the ad hoc Committee for Standardized Reporting Practices in Vascular Surgery of the AAVS/SVS, defined and categorized the severity of anatomic factors for AAAs, which they termed the anatomic severity grading (ASG) score.[10] We have previously shown a relationship between an ASG score greater than or equal to 14 with increased procedural difficulty, increased 30- day morbidity, and increased hospital costs.[11] In this subsequent study, our aim was to identify if and how preoperative ASG score can influence EVAR reintervention rates. Determining how ASG score impacts reintervention rates could further refine patient selection for EVAR by quantifying and standardizing the term "suitable anatomy." This type of improved patient selection would alter long-term EVAR outcomes by improving long-term endoleak, rupture, and survival rates of EVAR.

## METHODS

We completed a retrospective review of AAA patients from 2007 through 2011. Patients were identified using Current Procedural Terminology (American Medical Association, Chicago, Ill) codes 35081, 35802, 35102, 35103, 35953, 37204, 34800, 34802, 34803, 34804, 34805, 34830, 34831, 34832, 37204, and 75953. Those who had the three criteria of an index EVAR and subsequent reintervention procedure performed by the Division of Vascular Surgery at Eastern Virginia Medical School and an M2S (M2S Inc, West Lebanon, NH) three-dimensional (3D) reconstruction of a preoperative computed tomography scan were selected for inclusion. Patients were excluded if they underwent a fenestrated EVAR, or if the indication for EVAR was not an AAA. Preoperative M2S 3D reconstructions were ordered at the surgeon's discretion with some partners ordering routine preoperative M2S imaging on all patients.

The data collected included age, sex, medical comorbidities, past medical history, indication for index procedure, and indication for and type of reintervention. A secondary procedure was considered a reintervention if the indication was a local/vascular complication as defined by the SVS and North American Chapter of the International Society of Cardiovascular Surgery.[12] ASG scores were calculated by two independent blinded reviewers for the reintervention group from the M2S 3D reconstructions according to the AAVS/SVS guidelines (Table I).[10] The scores from the reintervention cohort were compared with a case-controlled cohort of EVAR patients from a previous study[11] that had their index procedure within

**Table II.** Average ASG score and score components for reintervention and nonreintervention cohorts

| | *Reintervention* | *Nonreintervention* | P |
|---|---|---|---|
| Total ASG score | 18 | 13 | <.0001 |
| AAA diameter | 52 | 52 | .83 |
| Neck length | .69 | 1.62 | .0001 |
| Neck diameter | .76 | .00 | <.0001 |
| Neck angle | .56 | .11 | .007 |
| Neck calcification/thrombus | 1.16 | .20 | <.0001 |
| Neck score | 3.16 | 1.93 | .0006 |
| AAA tortuosity index | 1.49 | 1.18 | .1 |
| AAA angle | 1.56 | 1.04 | .01 |
| AAA thrombus | 2.39 | 1.67 | .0005 |
| AAA branch vessels | 1.76 | .84 | <.0001 |
| Aorta score | 7.13 | 4.73 | <.0001 |
| Internal iliac artery | .33 | .33 | 1 |
| Iliac calcification | 1.31 | 1.36 | .8 |
| Diameter/occlusive disease | 1.96 | 1.18 | .001 |
| Iliac tortuosity index | .91 | .58 | .03 |
| Iliac angle | 1.00 | 2.31 | <.0001 |
| Iliac seal length | .67 | .24 | .04 |
| Iliac seal diameter | 1.62 | .24 | <.0001 |
| Iliac score | 7.80 | 6.24 | .003 |

*AAA,* Abdominal aortic aneurysm; *ASG,* anatomic severity grading.
Results are reported as means.

the same time period, had no reintervention, and had ASG scores previously calculated via identical methods. ASG scores and component scores (assigned on a severity scale of 0 to 3) are reported as averages for each group. AAA diameter, while not part of the ASG score, was reported in conjunction with the total ASG score. Values are recorded in millimeters.

Microsoft Excel 2010 (Microsoft Corporation, Redmond, Wash), was used to calculate *P* values via two-tailed Student *t*-tests where a *P* value of less than .05 was significant. The ASG scores and component scores were analyzed with respect to reintervention vs nonreintervention as well as several specific reintervention types vs those that did not receive that reintervention. An area under the receiver-operating characteristic (AUROC) curve was calculated using Stata/SE 12 (StataCorp, College Station, Tex). Data collection and image analysis were conducted with institutional review board approval.

## RESULTS

Of the 623 patients treated with EVAR for AAAs from 2007 through 2011, 79 (13%) had reinterventions of which 45 (7.2%) electively treated patients had preoperative M2S 3D reconstructions available for ASG score calculation.

The reintervention group had a mean age of 74 years with 80% male sex. The risk factors included hypertension (80%), coronary artery disease (31%), cerebrovascular disease (9%), hypercholesterolemia (69%), chronic obstructive pulmonary disease (53%), diabetes (20%), and renal insufficiency defined as a creatinine level greater than 1.5 (11%). This group was compared with a case-matched cohort of 45 EVAR patients that were free from reintervention. The case-matched group had a mean age of 74 ($P = .85$) and was 80% male ($P = 1.00$). The risk factors included hypertension (82%; $P = .79$), coronary artery disease (16%; $P = .08$), cerebrovascular disease (22%; $P = .1$), hypercholesterolemia (73%; $P = .8$), chronic obstructive pulmonary disease (33%; $P = .06$), diabetes (13%; $P = .4$), and renal insufficiency (22%; $P = .11$). In the reintervention group, 33 of the 45 were treated with a Medtronic (Medtronic, Minneapolis, Minn) endograft, while all 45 in the nonreintervention cohort were treated with Medtronic endografts. The remaining 12 in the reintervention group were treated with 2 Endologix (Endologix, Inc, Irvine, Calif), 1 Anaconda (Vascutek, Scotland, UK), 6 Lombard (Lombard Medical Technologies Inc, Wellesley Hills, Mass), 1 Excluder (W. L. Gore & Associates, Flagstaff, Ariz), and 2 Aptus (Aptus Endosystems Inc, Sunnyvale, Calif).

The reintervention group had a mean ASG score of 18 ± 5 (range, 8-30) compared with the case-matched nonreintervention cohort who had a mean ASG score of 13 ± 4 (range, 6-21; $P < .0001$). Neck, aorta, and iliac component scores were also significantly different between the two groups (mean neck score of 3.16 vs 1.93; $P = .0006$; mean aorta score of 7.13 vs 4.73; $P < .0001$; and mean iliac score of 7.8 vs 6.24; $P = .003$). The mean AAA diameter for all patients was 52 mm ± 14 and was not significantly different between the two groups. ASG score data analysis for the reintervention group vs the nonreintervention group can be seen in Table II. Average length of follow-up was 29 months (range, 1-65 months) for all 90 patients (average of 21 months [range, 1-41 months] for the nonreintervention group and an average of 37 months [range, 1-65 months] for the reintervention group).

After AUROC analysis, an ASG score of 17 was highly predictive of reintervention (sensitivity = 60%; specificity = 78%; positive predictive value = 73%; negative predictive value = 66%). An ASG score of <17 yielded a 34% reintervention rate, whereas an ASG score of ≥17 yielded a 73% reintervention rate ($P = .0002$). The inflection point of the AUROC occurred at an ASG score of 13. This score was highly predictive for freedom from reintervention (sensitivity = 93%; specificity = 47%; positive predictive value = 64%; negative predictive value = 88%) with a 64% reintervention rate at an ASG score of 13 and greater and a 22% reintervention rate at ASG scores below 13 ($P < .0001$). The AUROC was 0.8 (95% confidence interval, 0.7-0.9) indicating that the ASG score has moderate discriminatory power.[13] The lowest ASG score that yielded a 100% reintervention rate was 22. The highest ASG score with 100% freedom from reintervention was 7 (Fig 1). Complete AUROC analysis data can be seen in Fig 2 and Table III.

The majority of reinterventions fell into three categories: proximal extension cuff (n = 18; 40%), distal extension limb (n = 7; 16%), and type II endoleak embolization (n = 13;

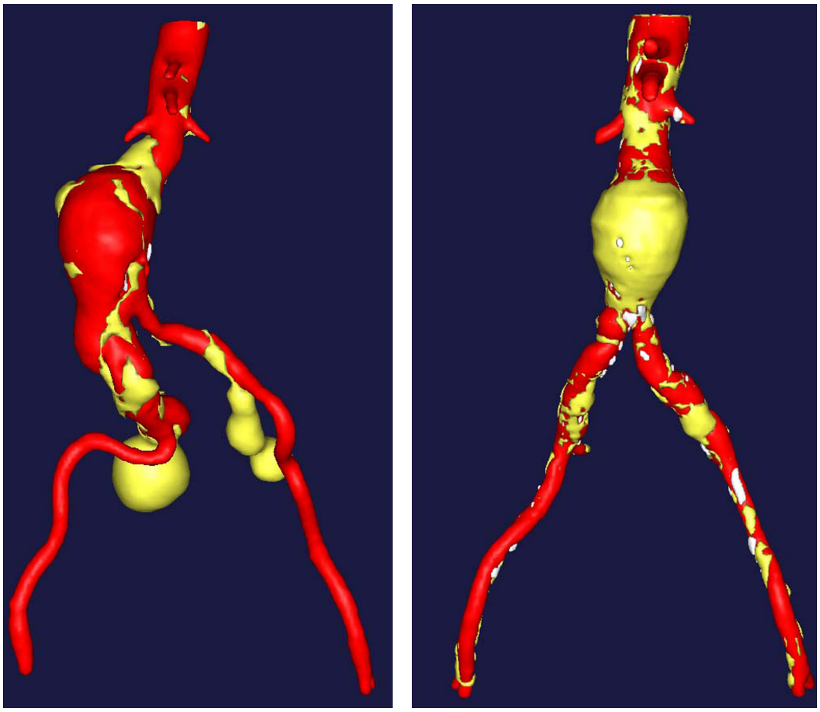

**Fig 1.** M2S three-dimensional (3D) reconstructions with an anatomic severity grading (ASG) score of 22 on the left and 7 on the right.

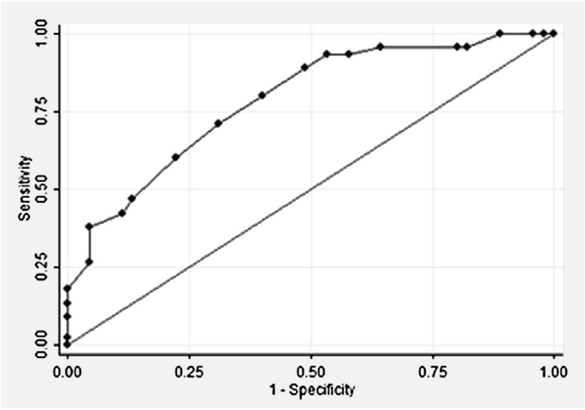


**Fig 2.** Area under the receiver-operating characteristic (AUROC) curve = 0.8 with a cutoff anatomic severity grading (ASG) score of 17.

29%). A fourth category, limb dysfunction, contained 12 (27%) patients: 6 (13%) graft limb thrombectomy with percutaneous transluminal angioplasty (PTA)/stenting, 2 (4%) graft limb PTA/stenting, and 1 (2%) each of the following: thromboembolectomy of access artery, PTA/stenting of the main body of a graft, conversion to aorto-uni-iliac, and axillary-to-femoral artery bypass.

Further subset analysis was conducted on those that received a proximal extension cuff, a distal extension limb, or a type II endoleak embolization. Those that received proximal extensions had a significantly higher mean total ASG score (19 vs 15; $P = .0005$), mean neck score (3.28 vs 2.36; $P = .047$), and mean aorta score (7.39 vs 2.36; $P = .004$) (Table IV). Those that received distal extensions had significantly higher mean iliac score (mean of 9.00 vs 6.68; $P = .013$) (Table V), and those that required an endoleak branch embolization had a significantly higher mean aorta branch score (mean of 1.92 vs 1.19; $P = .017$) and aorta score (mean of 7.23 vs 5.71; $P = .035$) (Table VI).

## DISCUSSION

Several studies have shown that as aneurysm size increases, the risk of graft-related complications increases.[14,15] Yet, intervening on smaller aneurysms before otherwise indicated does not offer a long-term survival advantage.[16] Interestingly, not only did the reintervention and the nonreintervention cohorts fail to exhibit a significant difference in aneurysm size, the groups had the same average aortic size of 52 mm, respectively. It has been reported that aneurysm size also correlates with increased rate of type Ia endoleaks,[14] and our analysis does corroborate this.

The rest of the anatomic analysis yielded some intuitive yet surprising results. It has been previously stated that aneurysms with increased anatomic complexity and more severe neck anatomy have a higher rate of type Ia endoleak.[14,17] This has been reaffirmed by our ASG score analysis, as every component of the ASG score as well as the

**Table III.** Detailed AUROC analysis

| *ASG score cutoff* | *Sensitivity, %* | *Specificity, %* | *PPV, %* | *NPV, %* |
|---|---|---|---|---|
| <6 | 100 | 0 | 50 | 100 |
| 6 | 100 | 2 | 50 | 100 |
| 7 | 100 | 4 | 51 | 100 |
| 8 | 100 | 11 | 52 | 100 |
| 9 | 96 | 18 | 54 | 80 |
| 10 | 96 | 20 | 54 | 82 |
| 11 | 96 | 36 | 60 | 89 |
| 12 | 93 | 42 | 62 | 86 |
| 13 | 93 | 47 | 64 | 88 |
| 14 | 89 | 51 | 65 | 82 |
| 15 | 80 | 60 | 67 | 75 |
| 16 | 71 | 69 | 70 | 70 |
| 17 | 60 | 78 | 73 | 66 |
| 18 | 47 | 87 | 78 | 62 |
| 19 | 42 | 89 | 79 | 60 |
| 20 | 38 | 96 | 89 | 61 |
| 21 | 27 | 96 | 86 | 57 |
| 22 | 18 | 100 | 100 | 55 |
| 25 | 13 | 100 | 100 | 54 |
| 27 | 9 | 100 | 100 | 52 |
| 30 | 2 | 100 | 100 | 51 |
| >30 | 0 | 100 | 100 | 50 |

*AUROC,* Area under the receiver-operating curve; *ASG,* anatomic severity grading; *NPV,* negative predictive value; *PPV,* positive predictive value.

**Table IV.** Detailed ASG score analysis for the proximal extension cohort

| | *Proximal extension* | *No proximal extension* | P |
|---|---|---|---|
| Total ASG score | 19 | 15 | .0005 |
| AAA diameter | 58 | 51 | .04 |
| Neck length | .83 | 1.24 | .2 |
| Neck diameter | 1.06 | .21 | <.0001 |
| Neck angle | .44 | .31 | .5 |
| Neck calcification/ thrombus | .94 | .61 | .1 |
| Neck score | 3.28 | 2.36 | .047 |
| AAA tortuosity index | 1.50 | 1.24 | .4 |
| AAA angle | 1.44 | .21 | .5 |
| AAA thrombus | 2.61 | .31 | .005 |
| AAA branch vessels | 1.83 | .61 | .008 |
| Aorta score | 7.39 | 2.36 | .004 |
| Internal iliac artery | .50 | .29 | .3 |
| Iliac calcification | 1.28 | 1.35 | .8 |
| Diameter/occlusive disease | 2.06 | 1.44 | .04 |
| Iliac tortuosity index | 1.22 | .63 | .002 |
| Iliac angle | 1.17 | 1.78 | .007 |
| Iliac seal length | .89 | .35 | .04 |
| Iliac seal diameter | 1.56 | .78 | .02 |
| Iliac score | 8.67 | 6.61 | .004 |

*AAA,* Abdominal aortic aneurysm; *ASG,* anatomic severity grading.
Results are reported as means.

**Table V.** Detailed ASG score analysis for the distal extension cohort

| | *Distal extension* | *No distal extension* | P |
|---|---|---|---|
| Total ASG score | 19 | 15 | .08 |
| AAA diameter | 50 | 52 | .7 |
| Neck length | .71 | 1.19 | .3 |
| Neck diameter | .57 | .36 | .5 |
| Neck angle | .43 | .33 | .7 |
| Neck calcification/ thrombus | 1.00 | .65 | .5 |
| Neck score | 2.71 | 2.53 | .8 |
| AAA tortuosity index | 2.00 | 1.28 | .04 |
| AAA angle | 1.43 | 1.29 | .8 |
| AAA thrombus | 1.86 | 2.04 | .7 |
| AAA branch vessels | 1.86 | 1.25 | .1 |
| Aorta score | 7.14 | 5.83 | .2 |
| Internal iliac artery | 1.00 | .28 | .007 |
| Iliac calcification | 1.14 | 1.35 | .5 |
| Diameter/occlusive disease | 1.43 | 1.58 | .7 |
| Iliac tortuosity index | .86 | 0.73 | .7 |
| Iliac angle | .86 | 1.72 | .03 |
| Iliac seal length | 1.43 | .37 | .005 |
| Iliac seal diameter | 2.29 | .82 | .002 |
| Iliac score | 9.00 | 6.86 | .01 |

*AAA,* Abdominal aortic aneurysm; *ASG,* anatomic severity grading.
Results are reported as means.

total ASG score itself were significantly different when comparing the proximal extension group with the rest of the EVAR recipients not requiring a proximal extension. It is important to note that neck diameter and overall ASG score are the most significant factors determining the need for proximal extension. Although it has been reported that neck angulation is an important factor in determining EVAR outcomes,[18] we did not uncover a significant impact of this component of the ASG score when considering the group that received proximal extensions, although it was significant when comparing the reintervention vs nonreintervention groups.

When considering the distal extension group, it is important to note that only the iliac score is significantly different between those that received a distal extension and those that did not. This seems to cause an increase in the total ASG score that is not quite significantly different from those that did not receive a distal extension cuff. Our interpretation of this is that treacherous iliac anatomy is the most important indicator of possible future need of a distal extension cuff for a type Ib endoleak, as it is the only component of the total ASG score that is significantly different. This finding demonstrates the correlation of a specific component score with its related reintervention.

As for the type II endoleak embolization group, it is most important to note the significant difference in the aorta score, particularly the AAA branch vessels component of said score. Sampaio et al reported that the presence of the inferior mesenteric artery along with an increasing number of patent branch vessels off of the aorta correlated with increased risk of developing a type II endoleak.[19] We have confirmed their finding using the ASG score, as the severity of the branch score increases with the presence of the inferior mesenteric artery and branch vessels on the aneurysm. It is also worthwhile to mention that of this cohort of patients who received embolization as treatment for a type II endoleak, some of them also received

**Table VI.** Detailed ASG score analysis for the type II endoleak embolization cohort

| | *Reintervention* | *Nonreintervention* | P |
|---|---|---|---|
| Total ASG score | 18 | 15 | .03 |
| AAA diameter | 60 | 51 | .03 |
| Neck length | 0.54 | 1.26 | .04 |
| Neck diameter | 0.62 | 0.34 | .3 |
| Neck angle | 0.38 | 0.32 | .8 |
| Neck calcification/ thrombus | 1.23 | 0.58 | .02 |
| Neck score | 2.77 | 2.51 | .6 |
| AAA tortuosity index | 1.38 | 1.32 | .8 |
| AAA angle | 1.77 | 1.22 | .5 |
| AAA thrombus | 2.15 | 2.00 | .6 |
| AAA branch vessels | 1.92 | 1.19 | .017 |
| Aorta score | 7.23 | 5.71 | .035 |
| Internal iliac artery | 0.46 | 0.31 | .5 |
| Iliac calcification | 1.23 | 1.35 | .6 |
| Diameter/occlusive disease | 1.38 | 1.60 | .5 |
| Iliac tortuosity index | 1.38 | 0.64 | .0006 |
| Iliac angle | 0.62 | 1.83 | >.0005 |
| Iliac seal length | 0.77 | 0.40 | .2 |
| Iliac seal diameter | 2.54 | 0.66 | >.0001 |
| Iliac score | 8.38 | 6.79 | .03 |

*AAA,* Abdominal aortic aneurysm; *ASG,* anatomic severity grading.
Results are reported as means.

a proximal and/or distal extension causing what may be an artificially significant difference in the iliac score and its components as well as the total ASG score. It would be worthwhile to examine a group of patients that had only a type II endoleak embolization. However, for our study, a sample size of 13 was already fairly small and removing those patients who had both reinterventions would have weakened the statistical significance of the other differences seen in the ASG score components.

Finally, when considering the original cohorts (reintervention vs nonreintervention), nearly every component of the ASG score is significantly different. Perhaps the most telling is the total score itself. Our AUROC analysis clearly showed that the ASG score is a good indicator in predicting reintervention. We have shown that at ASG scores of 13 and lower is highly predictive of freedom from reintervention, which correlates with our previous published data demonstrating that an ASG score of less than 14 also correlated with less operative difficulty, better 30-day outcomes, and smaller hospital costs.[11]

One of the major weaknesses in our study is the small sample size of the individual reintervention types. This is especially evident in the type II endoleak cohort and is explained above. It is possible that with larger sample sizes, we would have yielded similar conclusions to previous studies regarding specific anatomic components as risk factors for endoleak. Our sample size was also limited due to the necessity for a preoperative M2S 3D reconstruction to calculate the ASG score. This requirement may have resulted in an underrepresentation of patients with chronic renal insufficiency and also rendered us unable to control for endograft type because of the relatively small number of patients that had a preoperative M2S. We continue to expand on our database to gain enough power to perform multivariate analysis on the different reintervention types. A potential weakness also exists in the application of our AUROC results to the population as a whole. The data represent a group of 45 EVAR patients with a reintervention compared with a cohort of 45 patients without reinterventions, resulting in a reintervention rate of 50%, which is much higher than our real overall reintervention rate of 13%. We do believe that our results open the door to the applicability of the ASG score in everyday practice, and it certainly requires a validation study on a larger population with a reintervention rate closer to 13%. Additionally, a future study should attempt to elucidate any correlation of ASG score with the overall cost of AAA treatment, as several patients received more than one reintervention.

In conclusion, preoperative total ASG score strongly predicts reintervention after EVAR and could be a powerful tool for vascular surgeons and their patients as they decide on the proper course of treatment. It quantifies AAA severity in a standard numerical form that is easy to interpret. We have shown that the ASG score correlates not only with risk of reintervention but also the type of reintervention that may be needed. Use of a cutoff ASG score value predictive of prohibitive reintervention rates could help guide the decision between endovascular vs open AAA repair and perhaps render AAA treatment more cost-effective.

## AUTHOR CONTRIBUTIONS

Conception and design: PJ, SA
Analysis and interpretation: PJ, SA
Data collection: PJ, CC
Writing the article: PJ
Critical revision of the article: SA, JP
Final approval of the article: SA, JP
Statistical analysis: PJ, DD, JK
Obtained funding: Not applicable
Overall responsibility: PJ, SA

## REFERENCES

1. The EVAR trial participants. Comparison of endovascular aneurysm repair with open repair in patients with abdominal aortic aneurysm (EVAR trial 1), 30-day operative mortality results: randomised controlled trial. Lancet 2004;364:843-8.
2. Blankensteijn JD, de Jong SE, Prinssen M, van der Ham AC, Buth J, van Sterkenburg SM, et al. Two-year outcomes after conventional or endovascular repair of abdominal aortic aneurysms. N Engl J Med 2005;352:2398-405.
3. Lederle FA, Freischlag JA, Kyriakides TC, Padberg FT, Matsumura JS, Kohler TR, et al. Outcomes following endovascular vs open repair of abdominal aortic aneurysm a randomized trial. JAMA 2009;302: 1535-42.
4. The United Kingdom EVAR Trial Investigators. Endovascular versus open repair of abdominal aortic aneurysm. N Engl J Med 2010;362: 1863-71.
5. De Bruin JL, Bass AF, Buth J, Prinssen M, Verhoeven ELG, Cuypers PWM, et al. Long-term outcome of open or endovascular

repair of abdominal aortic aneurysm. N Engl J Med 2010;362: 1881-9.
6. The United Kingdom EVAR Trial Investigators. Endovascular repair of aortic aneurysm in patients physically ineligible for open repair. N Engl J Med 2010;362:1872-80.
7. Arko FR, Murphy EH, Boyes C, Nussbaum T, Lalka SG, Holleman J, et al. Current status of endovascular aneurysm repair: 20 years of learning. Semin Vasc Surg 2012;25:131-5.
8. Rutherford RB. Open versus endovascular stent graft repair for abdominal aortic aneurysms: an historical view. Semin Vasc Surg 2012;25:39-48.
9. Brewster DC, Cronenwett JL, Hallett JW, Johnston KW, Krupski WC, Matsumura JS. Guidelines for the treatment of abdominal aortic aneurysms. J Vasc Surg 2003;37:1106-17.
10. Chaikof EL, Fillinger MF, Matsumura JS, Rutherford RB, White GH, Blankensteijn JD, et al. Identifying and grading factors that modify the outcome of endovascular aortic aneurysm repair. J Vasc Surg 2002;35: 1061-6.
11. Ahanchi SS, Carroll M, Almaroof B, Panneton JM. Anatomic severity grading score predicts technical difficulty, early outcomes, and hospital resource utilization of endovascular aortic aneurysm repair. J Vasc Surg 2011;54:1266-72.
12. Rutherford RB, Baker JD, Ernst C, Johnston KW, Porter JM, Ahn S, et al. Recommended standards for reports dealing with lower extremity ischemia: revised version. J Vasc Surg 1997;26:517-38.
13. Fan J, Upadhye S, Worster A. Understanding receiver operating characteristic (ROC) curves. CJEM 2006;8:19-20.
14. Peppelenbosch N, Buth J, Harris PL, van Marrewijk C, Fransen G; EUROSTAR Collaborators. Diameter of abdominal aortic aneurysm and outcome of endovascular aneurysm repair: does size matter? A report from EUROSTAR. J Vasc Surg 2004;39:288-97.
15. Rockman CB, Lamparello PJ, Adelman MA, Jacobowitz GR, Therff S, Gange PJ, et al. Aneurysm morphology as a predictor of endoleak following endovascular aortic aneurysm repair: do smaller aneurysms have better outcomes? Ann Vasc Surg 2002;16:644-51.
16. The UK Small Aneurysm Trial Participants. Mortality results for randomised controlled trial of early elective surgery or ultrasonographic surveillance for small abdominal aortic aneurysms. Lancet 1998;352:1649-55.
17. Sampaio SM, Panneton JM, Mozes GI, Andrews JC, Bower TC, Karla M, et al. Proximal type I endoleak after endovascular abdominal aortic aneurysm repair: predictive factors. Ann Vasc Surg 2004;18:621-8.
18. Sternberg C, Carter G, York JW, Yoselevitz M, Money SR. Aortic neck angulation predicts adverse outcome with endovascular abdominal aortic aneurysm repair. J Vasc Surg 2002;35:482-6.
19. Sampaio SM, Panneton JM, Mozes GI, Andrews JC, Bower TC, Karla M, et al. Aneurysm sac thrombus load predicts type II endoleaks after endovascular aneurysm repair. Ann Vasc Surg 2005;19:302-9.

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